PRELIMINARY STUDY OF THE WESTERN YELLOW PINE

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I.--Introduction (A Summary)

Western yellow pine* is the most important commercial tree of nine of the twelve westernmost States. In California and Oregon it holds second place, and in Washington two species are more important. The cut in Washington, Oregon, and California of red fir, redwood, and western cedar exceeding that of the pine. In the amount of standing timber there are probably but two other species in the United States of equal importance. The reported amount of red fir in the west and of longleaf pine in the south exceeds that of western yellow pine. This tree and its products are little known outside of the region lying between the Pacific and the Plains. Within this area on the lower slopes, foothills, and mesas of the region of little rain, east of the summits of the coast ranges, it is better known and more commonly used than any other forest tree.

The reason for this widespread use is due to its occurrence in merchantable quantities within the principal areas of settlement and its close resemblance to eastern pines whose useful qualities were well-known to the settlers. They found the western yellow

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*Pinus ponderosa and varieties

pine in many ways inferior to the pines of the east, but in general it has proved a fair substitute and has been used satisfactorily in the building of homes, towns, railroads, and mines in the region of its occurrence. The usefulness of this tree in the present industrial development of the west and the great amount available for future development made a commercial study of the species desirable. The following report is neither complete nor final, but simply a bringing together of some of the most reliable information available at the present time. The tables of growth are the result of field work carried on by three field parties during the season of 1904, and of other parties during the period from 1900-1903. The map of commercial distribution is based mainly on information gathered by field parties and individuals of the Forest Service and Geological Survey. For certain regions (especially for those of the principal distribution of yellow pine) it will be found fairly accurate, for others less so. The map is intended as a graphic description of the distribution of western forests and not as an absolutely accurate outline of their limits.

The results of the study may be briefly stated as follows: Western yellow pine (Pinus ponderosa and varieties scopulorum and jeffreyi) is the principal commercial tree of the drier forest areas of the west. It occurs in merchantable quantities in all the States bordering and west of the Plains (South Dakota, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Idaho, Montana, Washington, Oregon, and California). One-half of the total area of yellow pine forests is found in the States of California and

Oregon. Less than 2 per cent of the total is found in Nevada, Utah, and Wyoming. The stand in the other states ranges from 2 to 11 per cent. The largest continuous forest of practically pure yellow pine is found in Arizona and New Mexico, extending from the San Francisco Mountains in Arizona to the headwaters of San Francisco River in New Mexico, a distance of 250 miles. Very extensive forests of yellow pine extend along the Sierras, but are more or less mixed stands of yellow pine, red fir, sugar pine, and incense cedar, with the yellow pine predominating.

The largest acre yields and best growth in height and diameter are found in the region of its principal distribution, (California, Oregon, Washington). Very dense stands are found in South Dakota and the northern Rocky Mountains, but the coast sizes are seldom, if ever, reached and the acre yields are therefore lower.

Yellow pine trees of great diameter and height are reported by botanists and others but trees over 200 feet in height and 5 feet in diameter are extremely rare. The principal cut in California comes from trees between 2 and 3 feet in diameter and 100 to 150 feet in height. The best acre yield measured was 82,000 feet. Ten to twenty thousand feet per acre were the common stands in the best forest areas. Trees in California under favorable conditions reach commercial sizes (12-20 inches) in 50 to 100 years.

The regions of the poorest development are found in the dry southwest (parts of Arizona and New Mexico). The slowest growth is found in the northern Rocky Mountains and South Dakota. In the Black Hills under normal conditions on thin soil and in

dense stands common to portions of the hills, trees 12-14 inches in diameter were from 150 to 200 years old, and under 100 feet in height. Old trees were found in all regions. Mature timber was commonly between 200 to 300 years old, occasionally trees were found with ages ranging between 400 and 500 years.

The total stand of western yellow pine in the United States, according to the Twelfth Census, is 125 billion feet on 34 million acres.

An estimate based on areas as shown in the distribution map would indicate 156 billion feet on 20 million acres. (See Table VII.)

Total cut reported for 1900 was 1 billion feet. The greater part of this was by small mills and for local use. Large mills with modern equipment, dry kiln and planers, and daily capacity of 50 to 100 M. feet have recently been erected in the principal pine areas. The best grades of lumber are manufactured by these mills into sash door and blind stock, siding and interior finish; the lower grades into ordinary lumber and box shooks. The finished products reach eastern and foreign markets and are sold under the name of western white pine. The wood of western yellow pine in color, weight, and texture closely resembles eastern white pine and for ordinary uses is an excellent substitute.

Fire is the principal enemy of yellow pine, doing greatest damage to seedling and pole stands. Reproduction of pine is good in regions with a fair amount of rainfall during the period of germination and early growth of seedlings, as in the

northern Rocky Mountains, South Dakota, and coast forests. Areas with scant reproduction are very common in the southwest. Reproduction has suffered from fires in all regions.

The principal problems of management are fire protection in the northwest, Black Hills, and coast forests, and reproduction with fire protection in dry forest areas of the southwest. Regulations of grazing and lumbering are necessary but secondary to other problems.

History

The first authentic account of western yellow pine* is the mention by Lewis and Clark in their report of exploration in the northwest, of a pitch pine occurring in South Dakota, Montana, Idaho, Washington, and Oregon. David Douglas rediscovered this pine in 1826 during his botanical exploration of Washington and Oregon. He first mentions it in a letter written while on a trip in the vicinity of Spokane, Washington, and suggested the name Pinus ponderosa, the heavy--wooded** pine. Later (having in the meantime received Hooker's newly published Flora Borcali Americana) he speaks of this pine as Pinus resinosa, following Hooker who extended the range of P. resinosa over the northwest America and

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*Synonomy
Pinus ponderosa, Lawson & Sons, 1836
Pinus resinosa, Hooker
Pinus benthameana, Hartweg
Pinus brachyptera, Engelmann
Pinus bearàsley, A. Murray
Pinus macrophylla, Torrey
Pinus parryana, Gordon
Pinus ponderosa var benthameana, Vasey
Pinus ponderosa var scopulorum, Engelmann
Pinus ponderosa (a) benthameana, Lemmon
Pinus ponderosa (a) brachyptera, Lemmon
Pinus ponderosa (a) nigricans, Lemmon
Pinus jeffreyi, Lambert
Pinus ponderosa var jeffreyi, Sargent

**In reality it is one of the lightest wooded pines, its specific gravity being close to that of white pine.

considered the two pines identical. Douglas collected seeds either in the vicinity of Spokane, Wash., or Roseburg, Ore., (on his trip south from the Columbia which resulted in the discovery of sugar pine) and these seeds he distributed, probably through the Royal Horticultural Society of London, to English horticulturists.

Douglas' death by accident in Hawaii and his busy life in the field up to that time prevented him from writing up and publishing the results of his explorations so that the first published description was not from his pen but is found in the Agricultural Manual issued in 1836 by Lawson & Sons. The tree is described under the name Pinus ponderosa, and its introduction by Douglas is mentioned. The description is that of young trees (under 10 years) grown in Great Britain.

Twenty-five years after its introduction (1836) it was planted extensively as an ornamental tree, in British and continental estates. The tree grew vigorously, was little partial as to soils, and fairly hardy. Cones from trees grown in England were exhibited as early as 1877. Trees from the earlier planting are now over 90 feet high and 2 to 3 feet in diameter. The varieties, jeffreyi and scopulorum have also been introduced and successfully cultivated. In the eastern United States a few trees have been planted and are reaching a fair development.

The explorers and botanists following Douglas in the western forests have nearly all collected and described this pine.

some using the old name, others giving it a new one. The fact that the pine was often collected on the borders of its range and under varying conditions of soil moisture and climate where regional variations might be expected to be greatest will account for new names and varying descriptions. Most of these early collectors were unacquainted with the tree in other regions, and good descriptions and material for comparison not easily obtained. Recent students of the tree, with collections representing the different localities of its range and with knowledge gained by personal observation in different regions are inclined to consider the various forms but regional variations of one species and include all under Lawson's name of Pinus ponderosa. The type is considered to occur in western Montana, Idaho, Washington, Oregon, and California. The large-coned form of California and Oregon is considered a variety under the name "jeffreyi" and the small-coned form of South Dakota and Nebraska, the southern Rocky Mountains, and southwest forms another variety under the name "scopulorum". Descriptions of these varieties have been made but owing to great individual variation and intermediate forms exact lines of difference cannot be drawn. The result is that existing definitions are conflicting and rather unsatisfactory. A close botanical study of the pine and its varieties over the whole range by some botanist with breadth of view and experience is necessary before an absolutely satisfactory description of the pine and its range can be obtained.

III.

Description

On account of the state of our knowledge of this pine, it has been considered desirable to enter into a brief botanical discussion of the species, bringing together in a compact form the facts gathered, that they may be an aid to future students of the tree.

Pinus ponderosa is placed by Englemann in his "Revision of the Genus Pinus", in "Sec. II, Pinaster", because of the umbonate awned apophyses of the cones of this species. The presence in the leaves of parenchymatous resin ducts, surrounded by strengthening cells and the bearing of subterminal cones and foliage in three-leaved persistent sheathed bundles, caused him to place it in "Sub-section 6, Ponderosae", of which it is the type and gives its name to the section. Under "Ponderosae" are associated 14 species (about 1/5 of the known pines) only one other sub-section (Taedae with 16) equaling this in number of species. Of these 14 species* eleven are found in western North America

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*Ponderosae--American

Pinus ponderosa--N. America
" leioplylla--Mexico
" tilifolia--Guatemala
" tenuifolia-- "
" pseudo-strobus--Mexico
" Montezumae--Mexico
" torreyana--California
" arizonica--Arizona, Mexico
" engelmanni--Mexico
" chihuahuana--Arizona
" contorta--N.W. America (includes var murrayana)

Old World

Pinus canariensis--Canary Island
" laricio--Southern Europe (includes var austriaca)
" thunbergii--Japan--China

and three are old world species. Three of the American trees are quite distinct, while the remaining eight are very closely related, the Mexican and Central American forms but little known and may prove on closer study to be but forms or variations of one species, of which Pinus ponderosa is the northern extreme of variation and P. Montezumae, the southern. Pinus ponderosa, as now defined, is the most widely distributed and variable of the pines and accommodates itself to a very wide range of soils and climate. The regions in which it is the principal commercial tree have, however, conditions of soil, moisture, and temperature approximately similar.

It is hoped the following description based on a collection made over the greater part of the range of ponderosa and compared with material previously collected (in National Herbarium and Forest Service Herbarium) may help and be a step to a more definite understanding of the regional variation of this widely distributed tree and furnish a nucleus for a definition of those more readily recognized forms which mark the end of extremes of its variations.

Three forms of the tree are recognized;

A. Pinus ponderosa--Typical form of western Montana, Idaho, Washington, Oregon, and California.

B. Pinus ponderosa jeffreyi--Southern Oregon, California, western Nevada, usually at high elevations.

C. Pinus ponderosa scopulorum--Typical of the Rocky Mountains and Colorado Plateau. Range includes South Dakota, Nebraska, Wyoming, eastern Montana, Utah, eastern Nevada, Colorado, New Mexico, western Texas and Arizona.

A. Pinus ponderosa

Occupies region of maximum bole development for coniferous trees. Exceptional size, rare, and found only where soil, moisture, etc., are exceptionally favorable. Mature trees range between 100 and 200 feet in height and 2 to 5 feet in diameter.

Cones medium sized, 2 - 4 inches long, light to dark brown, dull or glossy; end of scale only moderately thickened and not prominently armed; seed of medium size, brown ground, with dark markings grading into dark red forms; leaves usually in threes, 4 to 8 inches long, dark green, falling in normal healthy trees, the third season; bark yellow or red brown on mature trees in dry or medium dry situations, grey or black on young trees (i. e. rapid growing tree usually under 150 years old) and often on mature slow growing trees in moist situations or at high elevations. Different conditions of soil, moisture, exposure, and density of stand have a direct bearing on the appearance of the tree; the character of cone and seed being the most constant.

B. Pinus ponderosa jeffreyi

Occupies region of maximum cone and seed development conifers. The tree differs but little in general appearance from type A in form and size of ordinary trees, and where the two grow in same forest it is often practically impossible to distinguish between them without the cones. In size the development of jeffreyi is probably inferior to that of ponderosa. Character and color of bark is similar to that of A., but the black or gray barked forms are most commonly reported (probably due to the fact that young and

rapid growing trees produce the largest cones and collectors, who are always looking for the exceptional, most frequently get their material from the dark barked pines). The one characteristic that distinguishes this tree is the production of very large cones 6 inches or over in length with correspondingly large seeds. The cones and seeds are not uniform in size and shape but exhibit the same variation in color of seed coat, arming and thickening of cone scales, that are found in the most variable individual of A. and C. The seeds are light with dark markings and grade into dark red forms or are uniformly grey with dark markings. The ends of the scales are usually thickened and prominently armed, the prickle usually recurved the needles are borne in clusters of three and similar in size and appearance to those of A. Certain observers reporting them as lighter in color of a grey cast and with a characteristic odor.

C. Pinus ponderosa scopulorum

Occupies a region in which conditions for bole and cone production are not as favorable as in the regions occupied by A. and B. Maximum development of C. falls below or barely equals the average development of coast forms. Mature trees range between 75 and 150 feet in height and 1 to 3 feet in diameter, cones small, 1 to 3 inches long and are very variable in size, shape, and arming, even within narrow ranges. Forms closely resembling A. are common in South Dakota and in the southwest; forms that resemble B. are frequent and other forms occur that are more local and differ from the ordinary forms of A. and B.

The typical cone of the southwest is from 2 to 3 inches long, light to dark brown, not glossy, scale ends thickened and prominently armed often ending in a prominent beak; seeds are small grey with dark markings, or blackish, the red brown and light brown spotted forms are not common in the southwest, but quite frequent in South Dakota. Bark exhibits all characteristics of coast trees and is usually red brown or yellow brown on mature trees, grey or black on younger trees. The change from dark to light bark is prevented or retarded in the Rocky Mountains as on the coast by such factors as elevation, moisture, density, etc. The needles are shorter in South Dakota and at high elevations than on the coast, but approach or equal them in the better developed trees of the southwest. In regions where vegetative activity is low, two needled forms are found; where conditions are favorable three needled forms are most common. Excess of food and favorable season may result in bundles with as high as five needles. A single branch may show 2, 3, and 5 needled forms. It is not uncommon to find on a single branch long needles in three leaved bundles, followed by short needles mostly in twos, and a third year needles again in threes, showing the effect of alternating favorable and unfavorable seasons. In general it may be said that the cones of the coast forms are largest and increase in size and prominence of arming from north to south and the seeds change from brown spotted to grey forms while the needles are usually in threes, sometimes in fives. A similar change is also common to the eastern forms, the cones increase in size and arming from north to south, and seed coats change from light brown to dark

grey or blackish. Two-needled forms are common north and at high elevations; three-needled forms are common in the south, with occasional trees bearing 4 or 5 needles.

The typical form (A.) in the region of its best development has a long narrow spire-shaped or cylindrical crown, straight, cylindrical, gradually tapering bole, the bark varying from almost black through grey to yellow or red-brown. It is deeply and coarsely furrowed, smooth with thin, easily separating scales, or broken into long, irregular, flat plates by deep, longitudinal fissures, the surface of plates red or brown, the fissure black or grey. The roots are large and strong, with well-developed tap root in dry- penetrable soils. The usual system is with strong laterals and numerous secondary roots penetrating to depth of permanent moisture. The tree often grows in shallow soils with impervious rock or clay a few inches below the surface. On these situations the root system is entirely lateral and strongly developed on or near the surface.

In the eastern part of its range and in dry situations the tree has a less spire-shaped crown; mature trees often approach the round or flat-topped form of the eastern pines. Form of bole, character of bark and root system, similar in Rocky Mountains to those of coast forms.

IV.

Growth

The wide range of yellow pine, its variability, the many kinds of soils occupied, and moisture conditions, endured, together with the varying density of the forests in which it grows, lead one to expect great difference in the rate of growth of this tree in different regions and in different parts of a given region. It is not possible nor necessary at present to determine the rate of growth in height, diameter, and volume for all regions, sites, and densities. Data has been collected in four regions and a table constructed showing the variation in growth in the different regions. They will not be found to apply to all sites and conditions of a given region, but may be considered as fairly representative of the ordinary growth in the better forest areas of the regions represented. The range of variation between individual trees of a given region may be as wide as that between the growth of trees in the regions of best and poorest development. This table is meant as a guide and indication of the possibilities of the tree and may be of temporary use in determining general policies of management or for estimating stands in regions where local data has not been gathered. By testing the table with a number of average trees from the region in question the usefulness of the table for the solution of a given problem may be ascertained.

It is especially desirable in estimating stands with reference to cutting, to first test the table with sample trees.

Great errors are possible as trees of a given diameter may vary in height. And trees of the same height and diameter, but of varying age and density of stand, will (especially with small trees scaled by board rules) show considerable variation of board contents of the merchantable stem. The rate of growth in age, height, volume, on a basis of diameter breast high, is the result of the measurement of a large number of trees in the four regions compared. The regions indicated were chosen as representative of the coast, northwest, southwest, and extreme eastern conditions of growth. It is thought that the California figures will in general represent growth in California, eastern Oregon, and eastern Washington; the Montana figures represent growth in the north Rocky Mountains, western Montana, Idaho, and possibly eastern Washington and Oregon; the Colorado figures represent growth in the southern Rocky Mountains and Southwest, and apply to better forest areas of Colorado, New Mexico, Utah, Arizona, and eastern Nevada; the South Dakota figures represent South Dakota, Eastern Montana, and Wyoming. The exact limits of application can only be determined by test of a given locality.

Table I.--Growth

Diameter--Age--Height--Volume

Diameter	5 inches			10 inches			15 inches		
	Age years	Ht. ft.	Vol. ft.	Age years	Ht. ft.	Vol. ft.	Age years	Ht. ft.	Vol. ft.
California	25	26	..	40	50	..	65	74	75
Colorado	40	19	..	70	43	..	110	65	100
Montana	50	37	..	90	62	..	150	79	226
South Dakota	60	29	..	110	54	..	200	71	185

	20 inches			25 inches			30 inches		
	Age years	Ht. ft.	Vol. ft.	Age years	Ht. ft.	Vol. ft.	Age years	Ht. ft.	Vol. ft.
California	95	97	357	130	116	753	200	131	1417
Colorado	200	79	275	200+	90	575	200+	99	1045
Montana	200+	91	321	200+	102	672	200+	111	1108
South Dakota	200+	80	385	...	...	...	...	...	....

+ Indicates that tree was over 200 years old.

The necessity for checking tables with local trees is shown by the range in height of trees of the same diameter in a given region.

Table II--Height--Variation

Diameter	5 Ht. Ft. Range	10 Ht. Ft. Range	15 Ht. Ft. Range	20 Ht. Ft. Range	25 Ht. Ft. Range	30 Ht. Ft. Range
California	20-45	35-80	50-105	60-130	75-150	90-170
Colorado	15-30	30-60	40-85	55-105	65-120	80-130
Montana	20-45	35-80	50-105	60-120	75-130	90-140
South Dakota	20-35	35-65	50-90	60-105	------	------

In general California may be said to be the region of most rapid growth and maximum height and volume development. Adjacent regions in Oregon and Washington will probably show a similar development as to height and volume, but the number of years to produce a given size should increase with the distribution from south to north. Growth is extremely slow in the dense stands in poor soil in South Dakota, and comparatively slow in Montana when compared with California growth. In the southern Rocky Mountains and Southwest, as represented by Colorado, growth in diameter is more rapid than that to the north though much slower than of California trees. Colorado trees are below the northern trees in height and volume growth. The reasons for this variation in growth are probably found in the fact that on the coast, plentiful rainfall, good soil, and long growing season are found and stands are more or less open.

In the northern Rocky Mountains soil and moisture conditions approach or fall below California conditions and the growing season is short and forests more dense, resulting in slow growth but fair development. In the southwest and southern Rocky Mountains, soil and growing season approach in character those of California and the forests are open, but the amount of moisture is small as compared with other regions. This would naturally result in a rapid growth as compared with northern trees, but growth in height would not be as persistent. In South Dakota the stands measured were dense and on poor soil the amount of moisture fair and growing season short; conditions producing very slow growing trees with fair height development.

Variation in growth of individual trees measured in different regions would seem to indicate that even in the region of poorest development a combination of good soil, plentiful moisture, and open stand will produce individuals closely approaching in size the average trees of the region of maximum development, and in the same way in all regions the minimum growth in height and diameter is practically the same. It will therefore be necessary, if very accurate estimates be desired of the possibilities of a given region for timber production, to first determine the variation in growth of the locality to be managed and divide the region into areas with similar growth. For rough general estimates the table of average conditions should prove useful.

Distribution

The botanical range of western yellow pine (forms A, B, and C) is probably greater than that of any member of the genus; red fir alone among the western conifers having a range equaling that of this pine. It is reported from the region between the Gold and Coast ranges in British Columbia at 50° north latitude and extends south into the mountains of Mexico. The northern and southern limits of its range are only known approximately. It extends from situations near the coast in Oregon and Washington to the Niobrara River in Nebraska reaching nearly to the 100th meridian. It is also found in the Black Hills of South Dakota and in western Texas.

In general this tree may be said to be one of the common trees of the timbered West, occurring in every State of the region, and is met with in quantity, or as scattered individuals, in all the large timbered areas. The coast forests of Washington, Oregon, and California, and the upper forests of the high mountains, both of the coast and interior, are the regions where it is an unimportant element and seldom seen.

At medium elevations in the Rockies, Sierras, Eastern Coast, and Cascade forest, and on the Colorado plateau it is the tree of most importance and most frequent occurrence.

Yellow pine has been reported from near sea level in the Puget Sound country, Washington, to elevations near the timber

line in Colorado, where it is said to reach a fair development at 11,000 feet. The mean annual rainfall of the region of its principal occurrence (following the maps of the Weather Bureau) is between 10 and 50 inches. Most of the Weather Bureau stations are located away from or below the forests in the drier regions and it is probable that little, if any, growth of yellow pine in commercial quantities is found in regions where the annual rainfall is less than 20 inches. The distribution of the rainfall throughout the year, however, is probably a more important factor in determining the occurrence of commercial forests than the actual amount. The seasonal range of temperature endured by this pine is very great, and, though not determined accurately, probably lies between 110° above to 28° below zero, Fahrenheit. Very great daily ranges are also endured.

The soils upon which it grows and reaches a fair or good development include practically all the soils or lack of soils common to the West. It grows in deep alluvial soils along streams and in the beds of old lakes; in glacial drift and volcanic ash, and on slopes so thickly strewn with rocks that no soil is visible. It is often found growing in the fissures of bare granite or other outcrops, and in thin soils a few inches in depth above limestones, schists, slates, and other formations; and in deep, loose sands and stiff clays. The one condition absolutely necessary for growth seeming to be an amount of permanent soil moisture sufficient to allow germination and growth. This amount is relatively small as compared with amounts required by other species of the region.

Only a few scrubby pines, junipers, and oaks among the western forest trees seem able to develop normally with less moisture than yellow pine. This ability may be more apparent than real, for this class of trees with low, bushy stems or dense cones and accumulation of litter above the roots are able to prevent the evaporation of what little moisture they receive and so render the soil in which the roots ramify as moist as that occupied by many yellow pine forests.

The sites chosen by this pine vary with the locality--moisture is the determining factor. In Montana it is found on dry south slopes at high elevations, and on lower dry slopes and moist flats above or along the streams. In Dakota it is found on all sites from level or rolling flats to the roughest granite peaks and slopes. In southern Colorado it is found on the dry, flat-topped, broken or sloping mesas or table lands, where it ends abruptly on the steep slopes above bare, arid valleys, or follows these valleys into the high mountains occupying the lower slopes and basins, as the elevation increases. In southern Arizona and New Mexico the yellow pine forest often occupies only the narrow crest of the highest mountains. In California, Washington, and Oregon the range of conditions is as great as in the Rocky Mountains, and the pine is found on dry slopes at high elevations to the north and lower dry slopes in the upper foothills, occurring often in almost pure stands over large areas. In the dry, southern mountains of the coast the pine occupies only the moist lands, such as north slopes and tops of the ridges.

This apparent lack of uniformity in choice of site disappears when it is considered that in moist regions as the north Rocky Mountains and in dry situations as in the southwest, the dry sites of the one and the moist sites of the other have approximately equal amounts of permanent soil water, so that in both, conditions are favorable for the development of the pine.

The distribution of this species is thus seen to depend on the amount of moisture received and retained by a given site. This moisture condition resulting from a combination of factors, such as soil, drainage, exposure, latitude, and elevation.

A close study of existing conditions would seem to indicate that all areas capable of supporting tree growth and receiving and retaining a certain amount of moisture at a season favorable to the germination and growth of yellow pine are occupied by individuals of this species. The amount of moisture so received and retained is in excess of that required by its southern associates, the pinons, cedars, and oaks, and less than that necessary for the growth of its more northerly companions, the red fir, Engelmann spruce, white balsam, sugar pine, and incense cedar. The yellow pine is, therefore, able to hold successfully against all competitors the regions where this balance of condition is maintained, and it is probable that all such areas are at present occupied by yellow pine forests (if we except areas with forests destroyed by fire or cutting) and that it will be impossible to materially extend the areas of such forests by natural means. Artificial planting and care of seedlings may bring in border regions

and those with conditions favorable to growth but separated from the yellow pine forests by natural barriers which have prevented seeding. The existence of such areas is as yet unproven.

The permanency of the occupancy by the pine of a given region depends on the permanence of favorable conditions. A catastrophe such as fire or wind may destroy all seed trees over a large area and the ground be occupied temporarily (as the lives of trees go) by a quick seeding species. Several generations of this nomad may occupy the ground while the former dominant species is regaining its territory by seeding from adjacent timbered areas. The alternation of aspen and pine in the Black Hills of South Dakota and of scrub oak and chaparral with the pine in the southwest and coast regions are good examples of this sequence of growth. The length of the occupancy by the aspen, oak, or chaparral depends on the success of the pine in reseeding the old areas. Repeated fires may prevent any return of the pine and the balance be undisturbed for long periods. It may even allow the encroachment of the brush in the forest by destroying reproduction within the forest areas and when openings occur by the death of old trees the brush takes its place. Wide areas of old open pine forests are found where fire or other factors prevent seeding and the brush is apparently dominant and holds the territory or increases in number of individuals while the individuals of the pine are becoming fewer and no new territory is gained. Fire is practically the only factor preventing for any length of time the return of pine to large areas formerly occupied. The removal of the disturbing factor will in time insure

the return of the pine, though in many instances where the complete destruction of seed trees in wide areas has taken place the return will naturally be very slow and hindered by the presence of brush, which, by depriving the seedling pine of moisture and light, kills many and checks rapidity of growth in others.

The limits of yellow pine forest areas may be sharply defined as in regions where abrupt changes in elevation determine the amount of moisture a given area receives so that a certain contour line may divide the forest from the plain or desert. In other regions a very gradual increase or decrease of moisture takes place, the balance of conditions most favorable to yellow pine is disturbed and other species begin to appear and the pine recedes from a dominant place in the forest to an occurence as a scattered individual in other forest types; its presence due either to chance seeding or the presence of sites of small area more favorable to its growth than that of the dominant trees.

The tension zone between two types of forest may be very narrow, as in the southwest where one may pass from pure yellow pine forests to a forest of aspen, red fir, and Engelmann spruce by ascending a steep slope or by simply going from a south to a north slope at high elevations. A similar change from yellow pine to another type may be made in the same general region by a descent, a forest of pinons and cedars often occupying a low mesa at the foot of a steep slope or line of cliffs, above which a pure forest of yellow pine occurs. In other regions the tension zone is very wide,

the distribution of moisture being very gradual, so that individuals of two forest types may grow in intimate mixture and all reach a fair development. This tension zone may be so very wide that these mixed forests may be the characteristic ones of a given region, as in much of the Sierra region of California and the flats along streams and lakes in Montana and Idaho.

As has been shown the botanical distribution of yellow pine is very wide, and it is present in all the large forest areas of the West. The commercial distribution is narrower and the size and location of these areas of forest where this pine is the dominant or sole species are determined by the presence over wide areas of that balance of conditions just described which gives to the pine its advantage over all competitors.

The map of western forest areas and the following table drawn from the map will give the best possible general idea of the commercial distribution of yellow pine in the timbered west.

Table III

	Commercial Forests 98,242,600 acres		Non-commercial Forests 120,208,700 acres	
	Western Yellow Pine	Other Merchantable Species	Thin Stands Burns Cuttings	Total Forest
	Acres	Acres	Acres	Acres
Wyoming	109,700	4,148,100	2,795,100	7,053,900
Nevada	136,400	...	6,966,400	7,102,800
Utah	337,300	4,089,100	15,964,000	20,390,400
Colorado	607,300	4,703,800	8,901,700	14,212,800
South Dakota	820,200	...	188,900	1,009,100
Washington	2,749,100	10,408,600	13,153,100	26,310,800
Montana	3,115,900	9,041,800	6,965,500	19,123,200
New Mexico	3,241,300	954,800	11,555,000	15,751,100
Idaho	3,891,900	7,438,200	12,198,300	23,528,400
Arizona	4,603,400	188,000	13,605,600	18,397,000
Oregon	7,808,700	11,217,700	9,345,000	28,371,400
California	13,924,200	4,707,100	18,569,100	37,200,400
12 States	41,345,400*	56,897,200	120,208,700	218,451,300

Western yellow pine forests are 19 per cent of the total forest area and 42 per cent of the commercial area.

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* One-half of this acreage used as basis of estimate of total stand (see Table VII)

California and Oregon contain the greatest areas of yellow pine forest, the combined area of the two States being over 50 per cent of the total commercial forests of this type. The regions of greatest commercial occurrence and of its best development are thus identical. From this center the pine is distributed north and east along the eastern slopes of the Cascades and the Blue Mountains of Oregon, through northern Idaho and Montana to South Dakota. Distribution is also south and east from the center in California by the Sierras and by the desert ranges of Nevada and Arizona to the Colorado plateau and southern Rocky Mountains. The commercial distribution in British Columbia and Mexico is not known. Large forests of yellow pine are reported in the northern mountains of Mexico, but whether these forests are of ponderosa or Mexican species or varieties has yet to be determined. Reports also credit the region between the Gold and Coast ranges south of 53° north latitude with considerable area of yellow pine forest, though their extent is not known.

A comparison of the forest map with that of the life zones published by the Biological Survey shows the commercial forest area of yellow pine to lie almost wholly within the transition zone as defined by the biologists.

VI

Commercial Importance

This wide range of the species and the location of many of the principal areas of settlement in the valleys and along

streams of regions occupied by yellow pine forests has in the past resulted in a very general use of this tree. In many cases, as in South Dakota and portions of Arizona, New Mexico, and Colorado necessity forced the settlers to use this tree as it was the only one in their region reaching sizes suitable for construction. A forced use of this kind, had the tree proven of little value as a building material, would have meant its temporary employment and with increase of wealth and transportation facilities other material would have been substituted. The pine was, however, found to answer in most respects equally as well as any material that could be imported and even in regions where red fir, Engelmann spruce, tamarack, and cedar were found with the yellow pine the cuttings have often been almost entirely of this pine. The close resemblance of this species to eastern pines with which the settlers were familiar operated in favor of the yellow pine and against the little-known western species which would have been more satisfactory for certain purposes. This close resemblance (early botanists confused this tree with red pine) both in external character and quality of the wood to the well-known pine trees, and lumber of the east probably accounts for its almost universal use even when better trees of other species were available. The constant employment of the wood of this tree for the wide range of construction purposes to be found in a new and rapidly developing mining, commercial, or farming district gave the builders an intimate acquaintance with its qualities. For general construction, fuel, and fencing it proved satisfactory and the demand and use steadily increased, making it

today the standard construction lumber of the interior and mountain west, if you except the areas directly tributary to the great lumbering district of the coast.

This knowledge, accumulated by the early builders, spread rapidly and new uses are constantly being found due to the increasing development and prosperity in the region of the trees occurrence. As an instance, the growth of the fruit and vegetable industry of the west created a demand for light, strong boxes, a demand satisfactorily met by the wood of this tree.

With red fir, redwood, cedar, and hemlock of the coast this pine is destined to become one of the important and well-known timber trees of the east as well as the west.

Among the many uses to which the pine is put the following are the principal ones:

Fuel.--Used for culinary and heating purposes both directly and in the form of charcoal in the homes throughout the trees' range. Used also for production of steam in connection with the varied industries of regions where coal is not handy. Sawmill, locomotive, and donkey engines, and agricultural traction engines are among this class of pine fuel users.

Fencing.--In the agricultural districts yellow pine is often used for fence posts and panels, especially in regions where only inferior fencing materials are found. Cedar is preferred and used when possible. Fancy pickets and palings are manufactured for town and city fencing and are in demand.

House construction.--The log cabins of the early settlers in pine forest regions are built almost entirely of logs, in

the round or rough hewn, cut from this tree. The advent of sawmills closely following early settlement made frame houses possible and every part from foundation to shingles was often of yellow pine. In the early development, after the tent period, of the mining and other towns of the west, such as Deadwood, Denver, Durango, Albuquerque, and Flagstaff, this tree housed the greater part of the population. This is still true, but in a lesser degree, of some of these towns and other towns at the present time. Both dwellings and stores are often of this material.

Mines.--In the yellow pine districts the mines have and still use large quantities of this timber, both in the log and as lumber. The former for the underground operations and the latter for the various buildings above the surface. The fuel used in many instances is also pine.

Railroads.--This tree, furnishing ties, timbers, and lumber, has, especially in the southwest, made possible a rapid economical development of rail transportation. The Southern Pacific, Santa Fe, Denver and Rio Grande, and other western roads have and are still using large quantities of lumber, ties, and timbers for the construction and maintenance of their tracks, stations, and snow sheds.

General.--Besides these principal uses for yellow pine timber, many smaller, more or less local ones are found, such as its use for flumes, slides, sidewalks, bridges, boats, and numerous other uses calling for a light, fairly strong, and easily worked material. Less strong and durable than the southern pine and in

general heavier than the eastern white pine, its uses overlap or enter the provinces of both these materials. Though unsuited to all the uses of these eastern pines, yet for many it is their equal or a fair substitute. Today it is sold in the east in the form of sash, door, and blind stock, siding and moulding under the name of white pine, and it is said by the western manufacturers that the dealers are unable to distinguish it from like product of eastern mills, and that it is proving as satisfactory.

Tests of its strength and behavior under given strains have been made but not in a satisfactory or very comprehensive manner. Tests to establish its fitness for various uses are to be made in the near future by the Division of Products of the Forest Service. The result of known tests and a comparison with eastern pines is graphically represented in the following table. The species in the last column are used as a standard for the given quality. White oak for instance has a strength of 10 as compared with 6 for red and western yellow pines. These pines are therefore a little over half as strong as white oak.

VII

Forests

In the principal regions of its commercial distribution typical yellow pine forests are found. They occupy level, rolling, or gradually sloping areas often ending abruptly (especially in the mesa country of the southwest) on steep, barren slopes, or are broken or interrupted by deep canyons or lines of cliffs and rocky ridges. These forests are not absolutely continuous, but often surround or are divided by open grazing lands that give a park-like effect to the region. This effect is heightened by the absence of underbrush and the presence of a more or less dense growth of grass and other herbaceous plants beneath the trees. The trees themselves are usually large, mature, growing in groups, or widely separated, so that sunlight may reach the ground in all parts of the forest with but little interference of the crowns. The typical forest litter of leaves, twigs, decaying stems and branches being absent or found in small quantities near the base of the trees, and in many regions the only litter beneath the trees is a pile of dry cones, the accumulation of a number of seed years. These typical yellow pine forests much resemble the open longleaf forests of the south and may, where the surface is not too rocky, be as easily traveled by a man on horseback.

Forests which in general answer to this description are found in all yellow pine regions, but are more frequently met with in South Dakota, the southwest(where practically all the

forests are of this nature) and in the eastern slopes and foothills of the Cascade Mountains in Washington and Oregon. The varied topography and more abundant moisture of the northern Rocky Mountains and Sierras have produced a much wider range of conditions for forest growth than is found in the more uniform topography of the southwest. The principal result of the moisture distribution of the coast and northwest is to widen the tension zone between types by producing conditions where individuals of two adjacent forest types may develop normally and neither by especial adaptation or vigor be able to crowd the other from occupancy of the land. In the Sierra forests the yellow pine mingles with sugar pine, incense cedar, red fir, and white fir in varying quantities, the percentage of pine increasing with degrees of dryness of soil and usually with lessening elevations, while at higher elevations and degrees of moisture the other trees dominate the stands.

In the northern Rockies the yellow pine is frequently found in almost pure stands occupying dry, exposed slopes and dry belts bordering open lands along streams. On most flats it is found mingling with red fir, lodgepole pine, western white pine, and tamarack, and reaches its best regional development under these conditions. The percentage of pine in mixture is very variable and depends on chance seeding, or small local varieties in soil moisture favoring the pine.

In the southern Rockies and southwest, the pine has few associates; wide areas may bear no other trees (if we except narrow belts of hardwood along the streams). It here occupies

a distinct zone, above and below which are other distinct types of forests, and the change from one to the other may be and usually is very abrupt, as the topography of a given region determines the type. Above the yellow pine, aspen, red fir, white fir, and Engelmann spruce occur, but often extend into the yellow pine areas on northern slopes and along canyons where moisture conditions are similar to upper regions. Below the pine belt forests of pinons and cedar occur, with the pine extending into them along the streams.

Along the border between two types the members of each mingle, but the transition zone is usually very narrow, often less than a mile or none at all.

The forests of the Black Hills, South Dakota, are practically of one species over the entire area, if we except the belts of hardwood along streams, the aspen on burns, and a small area of spruce on moist slopes in the north central region of the hills.

Burns and cuttings on yellow pine land are common to the whole range of its distribution, but vary in character with the regions. In the southwest fires are less frequent, owing to the open character of the forests and the absence of undergrowth. Only along the edges of types where the dense forests of pine and cedar, or aspen, spruce, and fir furnish food for fires are several burns found. Here all the standing timber may be killed and the land occupied by aspen or scrub oak until the reproduction of the original forest species can creep in from the edges.

The common result of fires in yellow pine forests of the southwest is to destroy reproduction and litter, scar the bases of mature trees, and kill scattering individuals, thus gradually causing the forest to become more and more open, and allowing in certain regions a dense stand of scrub oak to come in.

Most of the cut over lands in the southwest have been merely culled of the larger and better trees and many of the older cuttings have a fair stand of seed trees which are gradually reproducing the forest. This second growth, owing to repeated fires, scant seeding, and unfavorable germination conditions, is very open and much brush has hindered development of the seedlings.

In the northwest, coast, and South Dakota regions, cutting and fire have usually been closely associated. Few large areas cut over have escaped fire. The result of these fires varies with the nature of the cutting and the location and character of the stand. With close cutting and much refuse of tops from lumbering in regions with dense underbrush or much reproduction of the pine, all living timber is often killed by the fires, and the areas occupied by dense stands of shrubby species. This is especially true in the California yellow pine forests.

Burns in light cutting and mature timber in rather open stands result in killing small growth and scarring the bases of large trees, or by killing a varying number of them the forest is opened and brush encroaches.

In the dense stands of small but mature trees characteristic of certain areas of the South Dakota forests all standing timber in tracts miles in extent has been killed by fire,

and where the fire has not killed the timber outright repeated fires have so checked the growth and lowered the vitality of the trees that they have been destroyed by insects and drought.

In general it may be said that practically all yellow pine forests on the Coast, northwest, southwest, and Rocky Mountain regions have been visited by fires, the reproduction totally or partially destroyed, many mature trees killed, scarred, or so weakened as to be unable to resist insects and drought. It is impossible at present to give even an approximate figure as to the extent of the area* actually denuded by fire and cutting or other causes. It is probably less than 10 per cent of the total commercial area.

The timber trees of types bordering the yellow pine areas and trees occurring in more or less intimate mixture with the pine are found in the following list:

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* These denuded areas when of appreciable extent and with a stand of less than 1,000 feet B.M. are included in the non-commercial forest on the distribution maps.

Region	Species
South Dakota	White Spruce
Wyoming	
Eastern	
Montana	
Southwest	Red fir
	Engelmann spruce
	White fir
	Blue spruce
	Mexican white pine
Northwest	Engelmann spruce
	Lodgepole pine
	Red fir
	Tamarack
	Western white pine
Coast	Red fir
	Incense cedar
	White fir
	Sugar pine
	Lodgepole pine
	Big tree

Red fir is the most common and widely distributed associate of the yellow pine and, with the exception of the Black Hills forest in South Dakota, is found in all parts of the range of this pine. A very slight increase of moisture above that required by yellow pine is sufficient to support this tree. It is, however, short and knotty over the greater part of the yellow pine range and never attains the size common to the region of its principal distribution in eastern Washington and Oregon.

VIII

Stands and Yields

The wide ranging yellow pine forests besides exhibiting great variation in the size and form of trees for different regions and for varying localities in the same region also vary within wide limits as to the density of stands of differing ages and sizes. In moist situations it is not uncommon to find areas with 16,000 seedling trees (one to three feet in height) to the acre and in the region of maximum development old stands have been measured with an average diameter of 29 inches and 67 trees to the acre. Fifty-four of these trees were over 20 inches in diameter and ranged as high as 45 inches D. B. H. Such stands are, however, very exceptional and not continuous over any appreciable area. These extremes show the possibilities of the trees in reproduction and development. The ordinary stands of the forest fall far below these limits, approaching or receding as the various conditions encountered are favorable or unfavorable to tree growth.

Except for rough general estimates of stands on large areas, average figures are of little value. A knowledge of the better stands of a region is more useful as these are an indication of the possibilities of a locality for tree growth and furnish a standard with which other stands on similar sites may be compared. Until fully stocked areas are produced under management, these better stands must be our source of information in solving the problems which hinge on the number of trees per

acre of different sizes and ages it is desirable to have to produce given results. It may be possible and is quite probable that better stands than these occurring in nature may be produced, but at present we may only be sure that as a given locality has produced a forest of a determined character a second forest of like character is possible if conditions which produced the first are duplicated.

To furnish data for comparison and determine the possibilities of certain regions in the line of timber production one hundred acres of the better stands of four localities (25 acres in each locality) were measured, and the results are given in the following table. The regions chosen are the same as those in which the growth measurements were made. Both classes of data coming from the same large forest areas. These measurements were confined to pure stands of pine as furnishing a basis for comparison for all regions.

Table V.--Maximum regional stand

Region	Diameter: Under 5" No.	Under 5" Vol.	5" - 9" No.	5" - 9" Vol.	10" - 14" No.	10" - 14" Vol.	15"-19" No.	15"-19" Vol.	20"and over No.	20"and over Vol.	Total No.	Total Vol.	Average diameter	Maximum diameter
						Ft. B.M.		Ft.B.M.		Ft.B.M.		Ft.B.M.	Inches	Inches
South Dakota	44	..	62	..	46	3,450	13	3,185	2	1,104	167	7,739	16	30
Montana	29	..	31	..	18	1,008	14	2,656	13	8,146	105	11,839	18	35
Colorado	3	..	9	..	12	420	13	2,015	11	4,900	48	7,335	18	35
California	17	..	14	..	10	270	9	1,377	21	28,763	71	30,410	24	50

In addition to these measurements of standing timber, where it was impossible to determine age and height for the different areas, other stands in two of the same regions were measured to show this development. Sample plots were taken in as fully-stocked, even-aged stands as the region afforded and average heights, diameters, and ages for these stands were determined.

In the following table the stands of small diameters came from the slow-growing dense forests of the eastern portion of the Black Hills of South Dakota, and the stands of large diameters from the rapid-growing forests of the Shasta country in California.

Table VI

Region	Number plot	Average diameter	Average height	Average age	Number trees per acre	Volume B.M.
		Inches	Feet	Years		Feet
S. D.	1	.*	2	7	16,800	....
" "	2	1	8	18	8,628	....
" "	3	2	16	28	6,216	
" "	4	4	30	41	2,128	
" "	5	6	35	82	1,066	
" "	6	10	48	119	408	6,100
Cal.	7	12	72	54	196	6,400
"	8	23	..	..	76	45,400
"	9	29	138	97	67	82,100

These tables give but rough indication of the stand and yields common to the west. Lack of cuttings in stands it was desirable to measure and the impossibility of finding in the time

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* Under 1 inch.

at hand dense stands of all ages and sizes for given regions make it impossible to obtain a good record. Such a record filling the gap in our present information must be supplied by future works.

The difficulties in the way of getting detailed information as to stands in a given region are small as compared to those in the way of making an estimate of the entire stand of yellow pine in the west. No attempt has been made to gather such data. General estimates that have a show of probability and are conservative are of some use, however, and it has been thought desirable to make such an estimate of western yellow pine, based on the acreages obtained from the map of distribution.

The following table gives the results by states. The average stand used is that of average commercial stands in the regions named, and the total area as obtained from the map is halved to allow for the smaller, irregular openings that occur in all large forest areas (and are especially prominent in dry yellow pine forests) such as barren slopes, canyons, untimbered ridges, streams, small lakes, clearings, burns, brush lands, and cuttings of small extent, intimately mixed in forest areas.

Table VII

State	Total Y.P. Area Acres	Area* used for estimate Acres	Average stand Feet B.M.	
California	13,924,200	6,962,100	10,000	69,621,000,000
Oregon	7,808,700	3,904,400	8,000	31,235,200,000
Arizona	4,603,400	2,301,700	5,000	11,508,500,000
Idaho	3,891,900	1,946,000	7,000	13,632,000,000
New Mexico	3,241,300	1,620,700	5,000	8,103,500,000
Montana	3,115,900	1,558,000	6,000	9,348,000,000
Washington	2,749,100	1,374,600	7,000	9,622,200,000
South Dakota	820,200	410,100	4,500	1,845,450,000
Colorado	607,300	303,700	3,000	911,100,000
Utah	337,300	168,700	3,000	506,100,000
Nevada	136,400	68,200	2,000	136,400,000
Wyoming	109,700	54,900	2,500	137,250,000
Total	41,345,400	20,673,100	7,600	156,606,700,000

The estimates of the Twelfth Census give 125 billion feet of yellow pine on 34 million acres. It is believed that the above estimate of 156 billion feet on 20 thousand acres is nearer the truth and below the actual amount of standing timber of this species in the west. Indications are that there is in round numbers 200 billion feet of this timber ready for the ax.

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* Rounded in hundred column, otherwise 1/2 total area.

IX

Lumbering

Exploitation of western yellow pine began with the first settlement of the west. It was used by the Indians, Spaniards, and Mexicans in the southwest, and later by settlers from the eastern United States. The first cuttings were light and restricted in area, and usually only the best trees were used. In the vicinity of towns and mines, where small timbers and fuel were in demand, the cut was often very close, and the areas were stripped of all useful materials. Fire and grazing destroyed reproduction, and these areas became practically bare of pine. Their extent is, however, small when compared with the total area of yellow pine forests. In general the local cutting for fuel, fencing, and mining timbers has had but little effect on the character and extent of yellow pine forests.

The finished product of the early days was in the form of hewn logs. The discovery of gold brought sawmills into the yellow pine regions. Small, portable mills were erected near the mines and towns, and supplied the local needs. The number of such mills and the amount of their output was directly dependent on the size and permanence of the settlement they supplied. The number of mills increased with the settlement of the country, and the principal cutting of yellow pine has, in the past, been by mills with a daily capacity ranging between 10,000 and 50,000 feet. The larger mills and larger lumbered areas are near or tributary to the larger towns of the yellow pine regions. Lead

and Deadwood in South Dakota, Denver and Durango in Colorado, Flagstaff and Williams in Arizona, Missoula and Kalispell in Montana, Spokane in Washington, Boise in Idaho, and Pendleton in Oregon have comparatively large areas of cut-over pine lands from which their supplies were drawn.

The total area of this cutting has not been accurately determined, but is probably less than 10 per cent of the total yellow pine area, and is mainly included on the map in the non-commercial areas so that a 10 per cent addition to the commercial area is necessary to make the present equal the original commercial forest. In but few regions have the forests lessened to any great extent except in states with but little commercial timber. Colorado, Utah, New Mexico, and Arizona have perhaps the greatest areas of cut-over lands as compared with the standing commercial forests.

While the greater part of the yellow pine cut has been by small mills supplying local needs, yet within the last decade large modern mills with a daily capacity of 50,000 feet or over and equipped with hand-saws, dry kilns, and planers, have been erected, and with their coming the true commercial exploitation of yellow pine may be said to here begin, for their products are not only used locally and in the nearby States of the plains and prairies, but are reaching eastern and foreign markets.

The number of large mills* and their location is approximately as follows: New Mexico, 3; Arizona, 2; Colorado, 2; California, 8; Oregon, 4; Washington, 4; Montana, 5; total, 28.

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*Only those mills whose cut is largely yellow pine are included.

These mills probably cut from 30 to 40 per cent of the yellow pine lumber manufactured in the west. This would mean a probable annual cut per mill of 10,000,000 to 14,000,000 feet, and a daily capacity in the neighborhood of 40,000 feet.

The methods of logging by these mills are adaptations of the best methods of the principal logging regions of the United States. The trees are felled with saws and skidded to the river, slide, or railroad with teams, big-wheel log wagons, or donkey engines and cables. The logs are carried to the mill by water, railroad, slides, or cables, or by a combination of these methods of transportation. The mills are usually located on, or having spurs connecting with the main railroad of the regions in which timber is being cut, and the manufactured lumber is shipped direct to market.

In certain regions, as California, flumes are used instead of spurs to connect mills with railroads. The cost of constructing and maintaining spur roads from the valleys into the high mountains being too great under present market conditions and flume transportation of lumber fairly satisfactory.

The character of the cuttings and the utilization of felled trees depends largely on cost of transportation, the local markets, and the character of the timber. The waste being greatest with short, knotty timber, long, difficult hauls, and no local demand for low grade material. With good timber, short, easy hauls, and local demand for fuel, fencing, mine timbers, and low grades of manufactured lumber, the utilization of trees is practicably as close as possible. In the mills, modern up-to-date

methods of manufacture are followed, band saws, dry kiln, and planers making it possible to put high grade materials on the market with the least possible loss in amount, kind, and grade of manufactured product.

The materials turned out include the usual stock sizes of lumber and dimension stuff both rough and dressed. Besides these a wide range of finished products are turned out. From the better grades, for distant shipment, door, sash, and blind stock, interior finish, ceiling, flooring, siding, etc., are manufactured, and from the lower grades slabs, box shooks, shingles, lath pickets, etc., are made.

Cost of logging and freight rates to eastern markets make it impossible to ship anything but the best grades east of the Mississippi. Probably less than 30 per cent of the cut can be made into materials suitable for long shipments, and the remainder must be disposed of at home. The few mills operating at present, and the great demand for such finished products as the mills can afford to ship, especially in prairie and plains states, make it possible for these mills to obtain custom in the smaller and larger towns of these regions, and ship direct with a saving to both producer and consumer. Little, if any, of their product reaches the general markets, and the lumber dealers of the east, as a whole, know practically nothing of the pine as a distinct kind of lumber, for it is sold east as white pine. The better grades closely resemble this eastern material, and are reported as making a satisfactory substitute.

The present cut of western yellow pine, as given in the Twelfth Census is almost one billion feet, the bulk of the cut coming from California, Oregon, and Washington. The total stand, as given by the same authority, is 125 billion feet, and from the estimate based on the distribution map, (see Table VII) 156 billion feet. In either case, with proper management of the forest, resulting in careful cutting, fire protection, and reproduction, these yellow pine areas should be able to yield a perpetual annual cut of a billion feet*.

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* It is believed that there is at least 200 billion feet of mature yellow pine in the West, and that these forests, if carefully managed and protected, could be made to yield an annual cut of 2 billion feet for the next hundred years, and after this first cutting yield three to four billion feet annually forever. They would thus furnish one-tenth of the present annual cut (of all lumbers) of the United States.

X

Enemies

The enemies of western yellow pine are those common to tree growth throughout the United States. Fire causes the greatest damage. Its effects are both direct and indirect. The damage done by insects, grazing, careless exploitation, fungi, and wind is often primarily due to fire. Climatic conditions, such as extremes of temperature, excessive moisture, or drought are enemies of the best development of the pine. Birds and mammals are, in a varying degree, able to check forest growth. The damage done by these various agencies is discussed more in detail under different heads as follows:

1. Mammals, Birds, Insects

The damage done by mammals other than man is principally to the young growth. Squirrels in certain regions, and especially in years of light seed production may harvest the entire crop of given areas, and thus prevent reproduction. Birds to a lesser degree, but in a similar manner, reduce the seedling growth. Sheep, goats, horses, and cattle, especially in seasons when forage is scant, eat and trample the small seedlings, and strip larger ones of foliage and buds. Porcupines strip the bark from young trees, completely girdling and killing some. The common injury is, however, to the leader of thrifty young trees, 3 to 6 inches in diameter. This may be girdled some 5 or 10 feet from the top and dies, leaving a dead snag to be enclosed by future growth.

In the vicinity of old Indian trails and camping grounds, large trees are often found with the bark removed from a point near the ground to a point 5 or 6 feet up the trunk. Some trees are completely girdled, others only partially stripped, and still alive. The Indians are said to use the inner bark for food and in making a fermented drink. With the exception of that done by grazing animals, the total damage by birds and mammals is small, and (except for occasional local problems) hardly a factor in the future management of yellow pine lands. Severe injury to large areas may be caused by overgrazing in regions where reproduction is scant and growth slow. This damage may be reduced to a minimum or entirely avoided by proper grazing restrictions. While the injury done by birds and mammals is mainly to the seed and young trees, the principal known damage by insects is to mature merchantable timber. Many insects are known to attack various parts of the tree, and are, in a certain degree, factors in preventing reproduction and growth. The bark beetles (Dendroctinus sp) do the greatest amount of damage, and in South Dakota and in the southwest are important factors at present in determining the management of yellow pine forest because of the large amount of dead timber left scattered through living stands, constituting a great fire danger, and also because of the spread of the insects from infested areas to other stands causing the death and loss of timber and the increase of danger from fire.

The work of the beetles is best known in the pure pine forests of the Black Hills of South Dakota where from 30 to 60 per cent of the mature timber over large areas (estimated at 168,000 acres on Black Hills Forest Reserve) has been killed. The extent of damage in other regions is not known, but areas of bug-killed timber have been frequently seen in the southwest, and are reported from the coast forests. In all cases the largest areas killed were mature or overmature timber of slow growth, or the growth had been seriously checked by fire or drought. The greatest damage known is that on the Black Hills Forest Reserve where the growth is extremely slow, and the areas in this region which received the greatest injury are those which have been seriously and repeatedly burned, and where the mature or over-mature trees formed a large part of the stands. Conditions were exceptionally favorable to the spread of the pest; plenty of food and ideal breeding grounds produced a multitude of beetles which spread to all parts of the forest, attacking and killing trees of low vitality. The spread of the beetles was very rapid, reaching its maximum in a few years, and then with the exhaustion of the food supply waned. It is probable that with adequate fire protection and the removal of old, slow-growing timber (thus destroying the principal food and breeding grounds) future insect ravages may be avoided. The beetles are probably present in all yellow pine forests (as individuals of low vitality that have been killed by beetles are met with everywhere), and when only a large number of

trees become at the same time unable to resist the attack of the beetles is there much danger. Fire is probably the only agency that will furnish the conditions necessary for the rapid multiplication of the pest. Protection and cutting of mature timber should, therefore, reduce danger to a minimum.

2. Fungi and Mistletoe

Western yellow pine is attacked by wood-destroying fungi, the common one (Polyporus sp.) being that producing the red rot of the heartwood. Old and injured timber is most often attacked, the fungus finding entrance at a point of injury, and spreading rapidly through the heartwood. The amount and extent of this damage is very variable, depending on age, vigor, and exposure of the timber.

This tree is also attacked by pine mistletoe (Phoradendron sp.) which fastens itself to the branches and small twigs of the pine, causing abnormal growth and a twisted, knotty appearance of affected parts. Where trees are badly affected, especially when infested early in life, their vitality is often lowered so that they become prey to insects and fire. Very small trees are found that are apparently killed outright by the parasite. These attacks are more or less local, and, at least in most of the observed cases in the southwest when any considerable number of trees were affected, occurred on the borders of the trees range where excess of moisture makes growth of parasite most vigorous. The extent of damage is small. The cutting of mature and infested trees will, both in the case of mistletoe and fungi, reduce danger and damage to a minimum. The presence of large

quantities of overmature injured timber is the only reason that the fungus is at present a factor in forest management. The removal of this class of timber from the forest will eliminate this factor from future consideration. Mistletoe, owing to its limited occurrence, has no bearing on the general problem of management.

3. Drought, Temperature, Wind

Adverse weather conditions check or prevent reproduction, and reduce the vitality of trees. Repeated drought and absence of rain during the periods when germination should take place prevents the starting of seedlings or kills those that start. Excessive moisture and low temperature cause rotting of seeds and damping off of seedlings, and favors the growth of fungi and mistletoe. Wide range of daily temperature, especially when night temperatures are too low for germination and daily temperatures high enough to start seed, may also prevent reproduction. The alternate thawing and freezing kills the germ in the seed, and also kills many exposed seedlings that are passing into their first winter after germination.

The yellow pine is frequently thrown by winds when grown on shallow, rocky soils and very exposed situations. The amount of damage of this kind is, however, small; overmature timber suffering the most.

Greatest damage by adverse climatic conditions is to seeds and seedlings. Drought kills but little mature timber, but, aided by fire and insects, it may, especially in old timber, become an important factor in shortening the life of trees.

4. Careless Lumbering

Two kinds of damage result from careless lumbering. In regions where the yellow pine reproduces slowly and on areas destitute of reproduction, clear cutting often prevents forest growth for a long period. In regions of good reproduction, careless felling may injure the young trees, and the accumulated litter of careless logging operations aid the fires which usually follow lumbering, and may often result in a partial or complete destruction of the forest and prevent for many years the return to normal conditions.

5. Fire

The greatest damage done to these western pine forests is directly or indirectly due to fire. Mature timber, especially in open stands with little undergrowth, receive but little visible damage. Seedlings, young timber, and old timber in dense stands or where much brush and litter occur are frequently killed outright. Yellow pine forest miles in extent, especially on the coast and northern part of the trees' range, have been completely destroyed and their places occupied by worthless brush. Fires in California and South Dakota have been especially destructive. Young and old growth were destroyed, and these areas will remain timberless for generations unless seeded or planted. Practically all yellow pine forests are repeatedly burned with the result that the stands are open, soil bare, reproduction scant or absent, trees fire-scarred and attacked by fungi and windthrown, growth

checked or vitality lowered finally causing death of trees by insects and drought, and increasing the damage due to unfavorable climatic condition, grazing, and careless exploitation.

Fires are mainly due to carelessness on the part of people who live in, about, or pass through forests, and the greater part of this damage can be eliminated by care in the use of fire, and by patrol of forest land during danger seasons.

Fire protection, removal of overmature timber, careful exploitation, and regulation of grazing will prevent the greatest part of damage from all causes now suffered by yellow pine forests. The present crop of merchantable timber will be secured, the normal growth maintained, a permanent forest grown over the entire area now timbered, and a second growth spring up on fire-wasted areas.

XI

Reproduction

Western yellow pine is an abundant and frequent seeder. Seed is produced annually by at least a few trees in every large forest area. Individual trees in favorable locations often bear a fair crop of seed four or more consecutive years, as is shown by bases of cones adhering to branches, and the accumulation of cones beneath the trees. Three year cones can be easily distinguished by the degree of weathering.

The following table is the result of counting the fallen cones of 40 trees* of different diameters. These were separated into four groups according to the age and diameter of the trees. The average diameter of the group is given, and average number of cones per tree which fell during the years 1901-3 inclusive.

There was no indication of a general seed year during this period.

Table VIII

Average diameter	Number of cones matured seed			Basis No. of trees	Notes
	Date cones	1903	1902	1901	
Inches		No.	No.	No.	
12		35	51	..	13	Young black barked trees
15		65	138	20	4	Young black barked trees
21		310	222	125	13	Intermediate dark barked trees
25		326	268	477	10	Old yellow or red barked trees

* Located in southwestern Colorado.

Cones from this region bear 100-150 seeds per cone and there are from 15,000-18,000 seeds to a pound so that the indicated yield is therefore from less than a pound to over 4 pounds per tree.

Favorable years probably bring a large number of trees in a given forest area into seed bearing. Reliable information as to the occurrence of such years is not obtainable. For the regions of the best reproduction in the coast, northwest, and South Dakota forests, they are reported as occurring at intervals of from 3 to 5 years. Accurate information as to the number of cones and amount of seed borne by a single tree during such seasons has not been obtained. A single tree in Colorado produced 1,025 cones. Indications are that the normal seed produced from mature trees ranges from 1-6 pounds. Locality, season, and vigor of tree causing great variation in trees of similar sizes. Seed is occasionally borne by very young trees, but as a rule trees under 50 years old bear but little seed unless in especially favorable situations. Large quantities of seed are borne by very old trees. Mature trees of all sizes and ages are frequent and abundant bearers of seed when conditions are at all favorable. Presence of cones is not always an indication of seed bearing. Many cones, especially on young trees, have undeveloped and unfertile seeds.

Cones mature and open during the fall of their second year. The greater part of seed drops from the cone in a few days after its first opening, (if the weather remains dry, a common condition over its range during the period of seed fall in October).

The cones are borne at the extremity of the branches, so that the falling seed aided by the wing (which imparts a rotary motion and increases its buoyancy) is borne even in dense stands andstill weather a fair distance beyond the crown of the parent tree. In open stands and strong air currents seed may be borne great distances. It is conceivable that very small seeds with firmly attached wing might be carried for miles by a storm in open country.

A tree in the open in southwestern Colorado 28 inches in diameter and 115 feet high scattered seed 700 feet from its base, in the direction of the prevalent wind and in fair weather. The following record of a tree in the open and in the same locality indicates the possibilities of the yellow pine as a producer and distributor of seed. The tree was 15 inches in diameter; 60 feet in height, and bore 250 cones. The direction of prevailing wind was north and the extreme distance of seed distribution was 330 feet in this direction.

The following diagram (which explains itself) shows the character of seed distribution by this tree.

A tree of this size should seed one-fourth of an acre. Four trees well placed should, with ordinary seed years, furnish and distribute enough seed to restock an acre.

The scattering of seed by the wind is the most common and satisfactory natural method. Other agencies are, however, responsible in a more or less degree for seed distribution. Squirrels and birds gather the seeds and carry them considerable distances. Their work, however, is not to be depended on as a means of commercial reproduction. The amount of seed they destroy more than offsets the help rendered. In certain regions, especially on steep slopes, and along canyons, the rains wash seed from the slopes and down the stream depressions. Good patches of reproduction are frequently found in the dry stream beds beyond the seed trees. The seedlings coming up in dense thickets where the sediment from a sudden storm was deposited. Birds, squirrels, or water are not to be depended on for seed distribution. Seed trees, well distributed over an area to be seeded, and aided by the air currents, are the only satisfactory and sure means of natural reproduction.

Of the immense amount of seed which falls only about 80 per cent is capable of germination under the most favorable artificial conditions. Fifty per cent is probably a high figure for the germination of wind-sown seed in the forest. The conditions most favorable to reproduction as indicated by its presence in quantity in the western forests is the presence of a moist, well-drained soil and daily range of temperature not excessive and favorable to germination and growth. Seed reproduction is,

however, usually present, unless destroyed by fire or other agencies, in all yellow pine regions where sufficient moisture is present during the season in which seeds germinate and the seedlings make their early development. The regions of best reproduction of yellow pine are found in the South Dakota, northwest, and coast forests. The forests of the southwest are as a whole deficient in reproduction. The distribution of rainfall in the southwest is probably an important factor in preventing reproduction. Early spring and summer months are very dry and the snow melts and ground becomes dry before the high temperature of the yellow pine forest areas are high enough to induce germination. Late summer rains start seeds that have retained their vitality through the alternate freezing and thawing of the winter and spring. These seedlings have but a short time to grow and enter the winter in a very tender condition. Many seedlings are killed in early winter before snow falls and during open winters by rapid thawing when frozen. When they thaw gradually even very tender seedlings in their first winter seem able to survive. The results of drought and freezing in southwest forests is to allow but few of the many seedlings which start to pass the danger period of the trees' infancy (the first 4 or 5 years of its life). The struggle for existence is so severe in these forests that any little disturbance of ordinary conditions which would have but little effect in the regions of good reproduction may render a southwest forest bare of seedling growth. Overgrazing is such a factor. The final result of conditions in these forests is to produce a

very open forest. In the lower forest areas spreading towards the plain and desert where these conditions of drought and exposure are exaggerated the most open, stunted forests occur and with the increase of elevation and moisture become denser and denser and reproduction more frequent until at points of permanent moisture the forest becomes more dense and where opportunity is afforded the reproduction abundant. Throughout the whole southwest local conditions produce excellent reproduction, but as a whole the region is deficient in the younger age classes with fire and grazing the principal disturbing factors.

In the northwest and coast forests, conditions are reversed. More rainfall is received than in the south and at a season suitable for early germination and growth. Daily ranges of temperature are less, and snows come earlier and remain permanently during the winter, thus protecting the seedlings. In California, rains are late but winter conditions are such that seedlings can establish themselves and are also favored by permanent snows. The condition most favorable to the development of seedlings is light and a small but constant amount of soil moisture within reach of their root systems. Having established themselves under these conditions with fire protection a forest is practically assured. They will stand much crowding at this stage and the stands remain dense until maturity, if not thinned by fire or other causes. Height growth in these dense stands is fair but diameter development is much restricted. Trees in the Black Hills requiring 200 years to attain diameters reached in

the open in 50 to 75 years. The presence of moisture in excess of the actual needs of the species, short growing seasons, and poor soils may also have a distinct effect on producing the dense stands of the north. The struggle for existence is less severe and individuals that in rapid-growing forests with little moisture would soon be crowded out persist much longer. The tree in the common acceptance of the term is a light-demanding species. Making little or no good development under the shade of other species or of dense stands of its own parents. Excellent reproduction may, however, spring up in thin stands and reach a fair development. Full light at all stages and only sufficient crowding to clean stems (the branches being very persistent, especially when strongly developed) and preserve forest conditions of moisture and litter under the trees are the ideal conditions for quality and quantity production. The densest stands of reproduction measured were in the forests of the Black Hills of South Dakota. Here stands of seedlings 3 feet high were found in which 10-20 thousand trees were found to the acre.

XII

Management

The yellow pine forests lying west of the 100th meridian exhibit two distinct sets of conditions. A definite forest in any one section may show both conditions, or only one. Under the first, the forest is open, practically pure (90 per cent of the stand is pine), the trees medium to good or poor development. The soil is dry for the greater part of the year and secures a large part of its moisture in the form of winter snows. Reproduction on these areas is usually very scant and often entirely absent over large areas. The ground between the trees is covered with grass or other herbaceous plants. Shrubby species seldom predominate. Characteristic forests of this class present an open, park-like effect, and on level areas much resemble the longleaf pine forest of the south. These open forests with scant reproduction will be referred to as Class A.

Class B represents an entirely different set of conditions. Though both grade into each other in many places by almost imperceptible degrees. Class B forests are usually less open than those of A and are frequently mixed (especially in northwest and on the coast, with only 40-60 per cent pine, or even less), the stand dense, and the trees of good or medium to very best development. Moisture conditions are at the maximum for yellow pine areas, and is received both in the form of snow and rain. The bulk of the moisture is, however, in the form of winter snows. The actual amount of moisture received may not be

in excess of that received by some Class A forests, but is received, retained, and distributed in such a way as to result in a fair or excellent reproduction of this pine. This reproduction inffavored localities may equal in number and vigor of seedlings the old field growth of loblolly pine in the south. Owing to this moisture induced reproduction of the forest trees and shrubby species, the Class B forest seldom presents the open, park-like effect found in Class A forests. Very open and badly burned forests (especially of California) may have such a dense stand of shrubs (chaparral) beneath and between the trees as to make travel in these regions very difficult, or practically impossible, without clearing.

Class A and Class B forests have each a distinct problem of management upon the successful solution of which the permanence and productivity of these forest areas depend. Class A's problem is reproduction, Class B's fire protection. In Class A forests fire protection and regulation of grazing and cutting are secondary but necessary to the successful solution of the main problem of securing adequate reproduction. The question of fire protection rises in a scale of importance with the siccess in securing reproduction.

In Class B forests reproduction is secondary, being practically assured if fire protection is had, and regulation of cutting, while necessary for the best reproduction, is more essential as a means of preventing fire. Regulations of grazing is of minor importance but a decided factor in securing reproduction.

Each yellow pine forest, whether it fall in Class A or B or in both, has its own peculiar local problems whose solution must be worked out on the ground. The general problems of protection and reproduction have also their local aspects, and only the broadest general rules for their solution can be made. The following rules are therefore but a rough general outline of the field of effort, the wide channels through which the successful solution of the problems may come, and will be of most value to those who attack these problems for the first time.

Rules

To secure the best possible reproduction on Class A forests.

1. Cutting should, as far as possible, be confined to areas which reproduce most readily (as along canyons, streams, north slopes), and which lend themselves most readily to fire protection. When necessary to extend cuttings over areas with little or no reproduction the cuttings should be light and extending over as long a period as possible, and follow good seed years and favorable seasons. No cuttings on these areas to reduce the stand to less than four good seed trees per acre and these well distributed over the acre. These trees to remain until reproduction is secured and old enough to resist fires.

2. Fire protection should be as effective as conditions permit. Areas with reproduction liable to fire damage and those on which fire prevents reproduction should receive most attention.

3. Number of grazing animals allowed in forest to depend on local conditions. Not to exceed the number the range will normally support without deterioration. As far as possible all animals kept from areas with small seedlings until these trees attain sizes not subject to injury.

II. To secure best possible fire protection in Class B forest.

4. First essential is a map showing forested area, and especially those areas with reproduction of such ages as to be most subject to fire damage. This map to show also all data that will aid in an effective fire administration, and may include the following: regions most subject to fire; points of origin of most fires; direction in which fire usually travels (prevailing winds); natural fire barriers, established fire lanes and other points of back firing; roads, trails, settlers' homes; points from which large areas of forest can be seen; signal and tool stations.

Besides this map, the important work to be done should include the determination of the season during which fires are most prevalent and destructive, and above all the organization of the ranger or other fire-fighting force, so that it may be called and distributed quickly when fires occur, and should be thoroughly instructed and trained, the actual details of fighting depending on local conditions. The main aim of administration should be to secure an effective fire patrol rather than a fire fighting force.

5. Cutting to be so regulated as to give least fire danger and aid reproduction, and may be closer than in Class A

forest. Two seed trees per acre should be left as a minimum, these to remain until reproduction is secured and large enough to resist fires.

6. Same regulations for grazing to apply as in Class A forest. (See Rule 3)